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Art. XX.—*Mt. St. Elias and its Glaciers;** by Israel C. Russell. With a map, Plate IV.

The National Geographic Society, in connection with the U. S. Geological Survey, has sent two exploring parties to Mt. St. Elias, Alaska. The first in the summer season of 1890, and the second a year later. The object of these expeditions was to explore the region about Mt. St. Elias, and learn as much as possible of its geography and geology, and if practicable to climb the mountain itself, which is thought to be the highest summit on the North American continent.

I had charge of each expedition, and it is my object to give here a brief account of the country explored.

The southern shore of Alaska is probably as wild and inhospitable as any coast in the world. Lofty mountains, snow-clad throughout the year, rise almost directly from the ocean, and send down not only scores but hundreds of glaciers to sea-level. From Cross sound to Kayak island, a distance of 300 miles, there is only one break in the iron-bound coast, in which ships can take refuge, that is Yakutat bay, fifty miles east of Mt. St. Elias. On the east side of Yakutat bay near its entrance, there is an Indian village, a mission and a trading-station. This is the nearest human habitation to Mt. St. Elias, and was the basis from which we began our explorations.

* Abstract of a lecture before the Geological Society of America, at Columbus, Ohio, Dec. 29, 1891.

Expedition of 1890.*

In 1890, I left the Mission at Yakutat, early in June, with eight companions, and proceeded by boat to near the head of Yakutat bay, where our tramp toward the interior began. We worked our way slowly northwestward towards Mt. St. Elias for fifty miles across mountain spurs and over glaciers. More than nine-tenths of the journey was over rough ice or on the névés from which the glaciers flow. We reached an elevation of 7500 feet on the north side of Mt. St. Elias, but were caught in the early winter storms and forced to retreat.

During this journey we became acquainted especially with the great névé fields on the mountains, and explored a large part of the northern border of the great Piedmont glacier, which is of the nature of a vast lake of ice, formed by the union and expansion of several large Alpine ice streams on the plain intervening between the mountains and the sea. This veritable *Mer de glace* is known as the Malaspina glacier. It was thus named by the Superintendent of the U. S. Coast Survey several years since, in honor of Don Alejandro Malaspina, an Italian explorer in the service of Spain, who visited the southern coast of Alaska in 1792 The Malaspina is the most interesting of all the glaciers in the St. Elias region, and will be briefly described a few pages in advance.

Expedition of 1891.

Early in June of the present year, I returned to the St. Elias region, and after calling at the Mission at Yakutat, landed at what is known as Icy bay, fifty miles west of Yakutat bay, and there began again the study of the geography and geology of the region to which I wish to direct attention.

With five camp hands for companions, I crossed the Malaspina glacier to the Chaix hills, and from there went up the Agassiz and Newton glaciers. Our highest camp was in the snow in the great amphitheater in which the Newton glacier rises, between Mt. Newton and Mt. St. Elias, and at an elevation of 8000 feet. We occupied it for twelve days, and during that time owing to clouds and snow storms, were able to make but one advance. On the day we did advance, we climbed to the divide between Mt. Newton and Mt. St. Elias and from there ascended the north slope of the great pyramid forming the summit of Mt. St. Elias, until we reached an elevation a little over 14,500 feet above the sea.

From the divide and while climbing the slope above it, we had an unobstructed view of the vast unexplored region

* A popular account of this expedition appeared in the National Geographic Magazine for May 1891.

north of the St. Elias range. The day was unusually beautiful and a strange land, which had never before been seen by man, lay spread out like a map beneath our feet. Having previously crossed the mountain system of which the St. Elias range forms a part, some 200 miles east of Mt. St Elias, and traversed the country to the northward, I expected on reaching the divide between Mt. Newton and Mt. St. Elias, to behold a similar region. I pictured to myself a comparatively low forested land, interspersed with lakes, and divided by streams, and perhaps giving some signs of human occupation. But I was entirely mistaken. What did meet my astonished gaze was a vast snow-covered region, limitless in its expanse, through which hundreds and probably thousands of barren, angular mountain peaks project. There was not a stream, not a lake, and not a vestige of vegetation in sight. A more desolate or a more utterly lifeless land one never beheld. Vast, smooth, snow surfaces, without crevasses or breaks, stretched away to seemingly limitless distances, diversified only by jagged and angular mountain peaks. The general elevation of the snow surface is about 8,000 feet, while the mountain peaks which pierce it are from ten to twelve thousand feet or more, in altitude above the sea. To the north I could see every detail in the forbidding landscape for miles and miles. The most distant peaks in that direction were forty or fifty miles away. To the southeast was Mt. Fairweather, sharply defined against the sky, although 200 miles distant. About an equal distance to the northwest are two prominent mountain ranges, the highest peaks of which appeared to be as lofty as Mt. Fairweather. These are in the vicinity of Mt. Wrangell, but no volcanic vapor could be seen about them. Whether any one of them was Mt. Wrangell or not I was not able to decide.

The view to the north called to mind the pictures that explorers give of the borders of the great Greenland ice sheet, where many rocky islands, known as *nunataks*, alone break the monotony of the boundless sea of ice. The region before me was a land of nunataks.

If those of my readers who are familiar with the Great Basin of the Far West, will fancy the most desolate portion of that arid region buried beneath a thousand feet of snow and ice, leaving only the southern slopes of the most rugged peaks exposed, they will have a mental picture of the land of desolation north of Mt. St. Elias.

Owing to long continued stormy weather, we were forced to abandon the hope of reaching the summit of Mt. St. Elias and returned to Icy bay.

On reaching the flat lands along the ocean, near the mouth of the Yahtse, we measured a base line three miles long and

obtained the necessary measurements of angles for determining the height of Mt. St. Elias and of a few of its neighbors. Computations based on these measurements, show that Mt. St. Elias has an elevation of 18,100 feet, plus or minus a probable error of less than 100 feet.

From Icy bay we tramped eastward along the coast to the head of Yakutat bay, and thus became familiar with the outer border of the Malaspina glacier. After reaching the head of Yakutat bay we explored the continuation of the same inlet, known as Disenchantment bay. The entrance to the inner bay was discovered by Malaspina in 1791, while searching for a passage between the Pacific and the Atlantic. At first the opening in the mountains at the head of Yakutat bay, gave hope that the long-looked for "Northwest Passage" had been found, but on entering it Malaspina learned his mistake and as an indication of his disappointment, named the inlet "Puerto del Desengaño," which has been changed by English writers, to "Disenchantment bay."

When Disenchantment bay was discovered, the Hubbard and Dalton glaciers had a greater extension than at present and uniting at Haenke island, blocked the inlet from shore to shore with a wall of ice similar to that now formed by the Hubbard glacier.

Disenchantment bay was next visited by Capt. Puget of Vancouver's expedition, in 1794, and was found to be blocked by ice, as had been described by Malaspina.

This is the last report we have of the condition of the ice in the bay, until our visit in 1890. When the Revenue Steamer *Corwin* called for us at the close of the season, we steamed up the bay past Haenke island, to within half a mile of the ice cliffs of the Hubbard glacier, and then turned back without exploring its eastern extension. It is reported that two prospectors in their search for gold visited the eastern arm of the bay a few years since, but of this excursion there is no record.

In the fall of 1891, I again visited the bay and with two companions explored its entire extent. We found it to be prolonged nearly due east from the Hubbard glacier for about ten miles, with a width of about three miles. From near the east end of this arm, beginning at what I have called Cape Enchantment, there is another arm, looking like a broad, placid river, from two to three miles wide, which runs south for over twenty miles, and extending beyond the mountains, expands into a circular lake-like water-body in the flat lands between the mountains and the sea. A partial survey of this southern portion of the bay was made, but stormy weather coming on, all instrumental work had to be abandoned.

Disenchantment bay is surrounded on all sides by magnificent mountains. In grandeur of scenery, it is second to none of the wild fiords of southern Alaska. It resembles Lynn canal, which is familiar to many Alaskan tourists, but is narrower, more like a river, and the bold, snow-covered, and ice-scored mountains are nearer at hand. The precipitous shores bordering the east and west arm are bare of vegetation, and the southern arm is also desolate, except at the extreme southern end, where the bases of the mountains are forested. Its shores throughout, up to an elevation of over a thousand feet, bear evidences of recent glaciation. An interesting feature in which the southern arm differs from the other portions of the inlet, is furnished by conspicuous gravel terraces, which score its sides in even, horizontal lines up to a height of about 150 feet. These terraces sweep about the bluffs of gravel enclosing the lake-like expansion at the south, showing that the water-body which made them did not find an outlet in that direction. As the entrance of the bay was blocked with ice when visited by Malaspina and Puget, it seems reasonable to suppose that the water-body in the southern arm owed its existence to the ice dam thus formed. The terraces are therefore about 100 years old. The numerous small stream-channels which cross them, show what has been accomplished in the way of subaërial degradation in a century.

Geology.

Concerning the geology of the St. Elias region our knowledge is very imperfect. Owing to the great extent of glaciers and snow-fields, opportunities for studying the formations beneath are exceedingly rare.

All of the rocks about Yakutat and Disenchantment bays, with the exception of a few intrusions of diorite and certain thin beds of limestone, are brown sandstone and dark shales. The dip of these strata is almost invariably to the northeast. Their thickness is great, but has never been even approximately estimated, owing to the fact that they have apparently, been crushed and overthrust on a grand scale. These beds constitute a well-defined formation, which has been named the Yakutat system. North and west of the area occupied by the Yakutat system, and for several reasons thought to be older, there is a series of shales, limestones and conglomerates, that have been named the Pinnacle system, on account of their appearance in a long line of cliffs at Pinnacle pass. In the cliffs at Pinnacle pass there is a bed of bowlders, which was observed in 1890, but its true character was not fully recognized until the following year. It was then found that what

is probably an extension of the same bed, increases very greatly in thickness toward the west and forms the Samovar, Chaix, and probably the Robinson hills. These hills are formed of sandy shale, filled with both angular and rounded stones and bowlders which represent a great variety of rocks. This terrane is a morainal deposit, and was formed in the ocean from the debris of glaciers which broke off in bergs. In the Chaix hills this deposit is over 4000 feet thick and is composed of conformable brown and gray strata, dipping northward at an angle of about ten degrees.

The topographic form of Chaix hills shows that they have been formed by a monoclinal uplift, of very recent date. Although composed of soft beds, they have not been deeply dissected by erosion. This conclusion as to the recency of the uplift to which they owe their prominence, is fully sustained by the fossils with which some of the beds are charged. All of the shells obtained are of species still living in the adjacent ocean.

North of the principal outcrops of the Pinnacle system are sandstones and shales that are lithologically undistinguishable from the characteristic rocks of the Yakutat system. These dip under the crystalline rocks forming the Augusta and St. Elias ranges, and form the actual bases of the mountains. From such facts as have been observed, I have ventured the hypothesis that the schists have been overthrust on to the sandstones and shales, and hence that the uplifting of the mountains is an event of very recent date. This conclusion was reached during the expedition of 1890, and was tested the following year, but without succeeding in fully demonstrating it, or finding evidence which would militate strongly against it. It must stand, therefore, as an interesting hypothesis, which awaits additional study.

The cliffs in which the rocks of the Pinnacle system are exposed at Pinnacle pass and in the Samovar, Chaix and Robinson hills, are monoclinal uplifts, due to the elevation of one side—in these cases always the north side—of faults. The Augusta and St. Elias ranges are also monoclinal uplifts. Nothing of the nature of anticlinal or synclinal folds was observed in the region explored. The prevailing and characteristic structure is monoclinal and very similar to the Great Basin type. The ranges including those immediately north of Mt. St. Elias have steep escarpments on one side and a gentle slope corresponding approximately with the dip of the strata, in the opposite direction. The ranges are short and in general trend northeast and southwest. Their steepest slopes are toward the southeast.

After the uplift of the mountains, glaciers seem to have taken immediate possession and to have protected the rocks from ordinary stream erosion. It is an interesting fact demonstrated to my own satisfaction at least, that the present ice drainage is consequent on the orographic structure. The glaciers in many instances follow the courses of faults, and ice falls occur in so many instances when the glaciers cross fault scarps, that their presence may be predicted from such a distance that only the general orographic structure is distinguishable.

Glaciers.

Although the St. Elias region is full of novelty and interest to the geographer and geologist, its chief attractions are for the glacialist.

The lower limit of perennial snow or the "snow line," is at an elevation of about 2000 feet above the sea. Above that elevation all of the mountains excepting the most precipitous cliffs are loaded with snow throughout the year. This snow forms the reservoirs from which flow hundreds of glaciers of the Alpine type. Some of these, as the Seward glacier for example, are fully fifty miles long and over three miles broad at the narrowest point. They are veritable rivers of ice which slowly drain away the snow that accumulates on the mountains. Besides the great ice-rivers there are very many secondary and tertiary glaciers, which do not form well defined streams. Some of these are of the same type as the small ice bodies that still linger in the cirques of the High Sierra of California, and illustrate the fact that the term "glacier" has a wide range so far as the size of the ice bodies to which it is applied, is concerned

The glaciers of the Alpine type which flow southward from the mountains, for fully a hundred miles west of Yakutat bay, unite on the plain between the base of the mountains and the sea, and form one immense *Piedmont glacier*. This has been named the

Malaspina Glacier.

Area.—This glacier extends with unbroken continuity from Yakutat bay seventy miles westward, and has an average breadth of between twenty and twenty-five miles; its area is approximately 1500 square miles, or intermediate in extent, between the State of Rhode Island and the State of Delaware.

The Malaspina glacier is a vast, nearly horizontal, plateau of ice, with a general elevation of about 1500 feet. The central portion is free from moraines and dirt but is rough and broken

by thousands and tens of thousands of small crevasses. Its surface is broadly undulating, and recalls the appearance of portions of the rolling prairie lands west of the Mississippi. It is in fact a dreary and lifeless prairie of ice. From the higher swells of its surface one may see for miles in all directions without observing a single object to break the even monotony of the broken ice plain.

On looking down on the glacier from an elevation of two or three thousand feet on the hills bordering it on the north, even on the wonderfully clear days that follow storms, its limits are beyond the reach of vision.

Moraines.—From any commanding station overlooking the Malaspina glacier, as from the summit of the Chaix hills for example, one sees that the great central area of clear, white ice, is bordered on the south by a broad, dark band formed of bowlders and stones. Outside of this and forming a belt concentric with it, is a forest covered area, in many places four or five miles wide.

In a general view, by far the greater part of the surface of the glacier is seen to be formed of clear ice; but in crossing it, one comes first to the moraine and forest covered border, which owing to the great obstacles it presents to travel, impresses one as being far more extensive than it is in reality.

The moraines not only cover all of the outer border of the glacier, but stream off from the mountain spurs that project into its northern border. One of these trains starting from a spur of the Samovar hills crosses the entire breadth of the glacier and joins the marginal moraine on its southern border. This long train of stones and bowlders is really a highly compound medial moraine, formed at the junction of the expanded extremities of the Seward and Agassiz glaciers. These two great ice-rivers are entirely above the snow line, and the debris which they carry only appears at the surface after the ice descends to the Piedmont region where the annual waste is in excess of the annual supply. The stones and dirt previously contained in the glacier are then concentrated at the surface, owing to the melting of the ice that contains them. This is the history of all of the moraines of the Malaspina glacier. They are formed of the debris brought out of the mountains by the tributary Alpine glaciers, and concentrated at the surface by reason of the ablation of the ice.

Lobes.—The Malaspina glacier consists of three principal lobes, each of which is the expansion of a large tributary ice stream. The largest lobe has an eastward flow, toward Yakutat bay, and is supplied mainly by the Seward glacier. The next lobe to the west, is the expanded terminus of the Agassiz glacier; its current is toward the southwest. The third great

lobe lies between the Chaix and Robinson hills, and its main supply of ice is from the Tyndall and Guyot glaciers; its central current is southward. The direction of flow in the several lobes explains the distribution of the moraines about their borders.

The Seward lobe melts away before reaching Yakutat bay, but its southern margin has been eaten into by the ocean, forming the Sitkagi bluffs. The Agassiz lobe is complete, and is fringed all about its distal extremity by broad moraines. The Guyot lobe pushes boldly out into the ocean and breaking off, forms magnificent ice cliffs which are the finest of any of the tide-water glaciers of the Pacific coast. The waves undermining these cliffs, cause large masses of ice to break away and topple over into the sea, thus forming great numbers of bergs. This is the only instance known in Alaska, where a glacier advances into the open ocean.

Surface of fringing Moraine.—A peculiar and interesting feature of the moraines on the stagnant borders of the Malaspina glacier, is furnished by the lakelets which occur everywhere upon them. These are found in great numbers both in the forest-covered moraine and in the outer border of the barren moraine. They are usually rudely circular and have steep walls of dirty ice, which slope towards the water at high angles, but are undercut at the bottom, so that in a vertical section they have something of an hour-glass form. The crater-like walls are all the time melting, and the morainal material which forms the upper two or three feet of their rims, is undermined and slides and rolls down the steep slopes, and accumulates in the basins below. These lakes last from year to year, but are finally drained, usually through a crevasse or opening of some sort at the bottom, and the basins are left with a deep filling of bowlders and stones. As the general surface of the glacier melts away, the ice beneath these thick accumulations of debris is protected and left in relief as the less deeply covered surface melts. The debris is thus raised on a pedestal, but does not behave like a single great bowlder. It slides away in all directions and a pyramid of ice sheathed with debris is the result. What was a crater-like depression, possibly seventy-five or a hundred yards across and a hundred feet deep, becomes in this way a pyramid fifty or sixty feet high. These pyramids are of the nature of the sand cones so common on many glaciers which are covered with light moraines, but instead of being annual as are most sand cones, they are perennial and only pass through their cycle of change once in several years. The alternate formation of lake basins and of debris pyramids, has an important effect in breaking up the stones and bowlders of which the moraines

resting on the stagnant glaciers, are composed. The rolling and sliding of the debris down the sides of the lake basins as they enlarge, and from the steep sides of the debris pyramids as they waste away, cause it to become more and more broken.

While traveling over the moraine-covered surfaces of the stagnant portions of the glaciers, especially on bright sunny days or when rain is falling, one is constantly startled by the rattle of stones and bowlders as they roll down the steep walls of the lakelets and plunge with a great splash into the muddy waters below.

This constant movement in the moraines whereby the blocks of which they are composed are broken finer and finer, is confined principally to the stagnant portions of the glaciers. When the glaciers are moving, lakelets cannot form for the reason that their basins become broken, and the water escapes.

Forests on the Moraines.—The outer and consequently older portions of the fringing moraines, are covered with vegetation, which in places, particularly near the outer margin of the belt, has all the characteristics of old forests. It consists principally of spruce trees some of which are three feet in diameter, and cottonwood, alder, and a great variety of shrubs and bushes, together with rank ferns which grow so densely that one can scarcely force a passage through them. The vegetation grows on the moraines resting on the ice, which in many place is not less than a thousand feet thick.

The vegetation is confined principally to the border of the Seward lobe. Near Icy bay it forms a belt five miles broad, but decreases in width toward the east, and is wanting at the Sitkagi bluffs, where the glacier is being eaten away by the sea. This is an interesting fact, for the reason that on the maps of this coast published by Vancouver, a cape is indicated at the locality where the glacier now comes down to the ocean. Evidently the cape has been cut away during the past one hundred years, and the recession has progressed until the forest covered border of the glacier has been removed. The forests appear again on the margin of the glacier to the east of Sitkagi bluffs, and also on the north border of the glacier. But on the portion adjacent to Yakutat bay it is wanting; the flow of the ice is toward Yakutat bay, which probably accounts for the absence of vegetation on that portion of the glacier. It is only on the stagnant border of the ice sheet that forests occur. The forest-covered area is by estimate, between twenty and twenty-five square miles in extent.

Drainage.—The drainage of the Malaspina glacier is almost entirely inter glacial or sub-glacial. There is no surface drainage, excepting in a few localities where there is a surface slope,

but even in such places the streams are short and soon plunge into a crevasse or a moulin and join the drainage beneath.

On the lower portions of the Alpine glaciers, tributary to the Malaspina, there are sometimes small streams coursing along in ice channels, but they are short-lived. On the borders of these tributaries there are frequently important streams, flowing between the ice and a mountain slope, but where these come down to the Malaspina, they flow into tunnels and are lost to view.

Along the southern margin of the Malaspina glacier, between the Yahtse and Point Manby, there are hundreds of streams which pour out of the escarpment formed by the border of the glacier, or rise like great fountains from the gravel and bowlders at its base. All of these streams are brown and heavy with sediment and overloaded with bowlders and stones.

One of the largest streams draining the glacier is the Yahtse. This rises in two principal branches at the base of the Chaix hills, and flowing through a tunnel some six or eight miles long, emerges at the southern border of the glacier as a swift, brown flood, fully one hundred feet across and fifteen or twenty feet deep. The stream after its sub-glacial course, spreads out into many branches, and has built up an alluvial fan which has invaded and buried thousands of acres of forest. In traversing the coast from the Yahtse to Yakutat bay, we crossed scores of ice water streams which drain the ice field to the north. The greater part of these could be waded, but some of them are rivers which it was impossible to ford.

The most interesting of these is Fountain stream. This comes to the surface in one great spring fully one hundred feet across. The water rises under such pressure that it is thrown twelve or fifteen feet into the air, and sends up jets of spray six or eight feet higher. It then rolls seaward, forming a broad, swift river which divides and spreads out in many channels both to the right and left and has inundated several hundred acres of forest land with gravel and sand. Where the streams flowing away from the glacier are large, they divide as do the Yahtse and Fountain, and enter the sea by several mouths. When they are small, they usually unite to form large rivers before entering the ocean. The Yahtse and Fountain, as we have seen, are examples of the first, while Manby stream is an example of the second class. This rises in hundreds of small springs along the base of the escarpment formed by the great glacier, and flowing across a desolate torrent-swept area, unite just before reaching the ocean into one broad swift flood of muddy water, much too deep for one to wade.

All of the streams where they leave the glacier are overloaded and at once deposit the coarser portions of their burdens. Those which bifurcate, continue to build up their channels all the way to the sea; while the rivers, formed by the union of many small branches, excavates channels, the depth of which is regulated by the elevation of the land above sea level. All of the streams bear quantities of debris to the ocean, but there their work ends. The waves and currents in the ocean seize the debris delivered to them and build it into beaches and bars. Nearly all of the streams near their mouths are turned westward on account of sand bars thrown across them by the prevailing ocean currents. Nothing of the nature of stream channels beneath sea level is suggested, or could reasonably be expected.

On the border of the glacier facing Yakutat bay the drainage is different from that on the southern border. The flow of the ice is there eastward and instead of forming a bold, continuous escarpment, ends irregularly with a low frontal slope.

The principal streams on the eastern margin in 1891, were the Osar, Kame and Kwik. Each of these issues from a tunnel and then flows for some distance between walls of ice. Of the three streams, mentioned, the most interesting is the Kame. This issues from the mouth of a tunnel in the ice about three miles back from the actual border of the glacier, and flows for half a mile in a narrow cañon with walls of dirty ice fifty feet or more high. The cañon then expands and forms a valley bordered by moraine-covered hills of ice, which gradually widens toward the east, until it merges with a low marshy tract bordering the shore of the bay. Well rounded sand and gravel is being deposited by this stream in large quantities. This covers the ice over which the stream flows, and during former stages, was deposited in terraces along the lower portion of the channel. These terraces, in part at least, rest on ice. The rounded and worn condition of the gravel and sand brought out of the tunnel, is proof that it has had a long interor sub-glacial journey.

On the north side of the open channel of Kame stream there is a sharp ridge of well rounded gravel which runs parallel with the present river, and in places can be seen to rest on an icy bed. This was evidently deposited by a stream similar to the present one, but which flowed fully one hundred feet higher. This ridge of gravel seems to be of the same general character as the Kames of New England and other glaciated regions.

Near the shore of Yakutat bay, Kame, Osar and other streams of the same character, spread out in lagoons and sand flats, where the finer material which they carry is deposited.

Sometimes this debris is spread out on the ice, and forms level terraces of sand and mud, which become prominent as the glacier wastes away.

The formation of osars seems fully explained by the subglacial drainage of the Malaspina ice sheet. On the north side of the glacier there are many streams which flow into tunnels and carry with them large quantities of gravel, sand and mud; while on its southern and eastern margin many streams emerge from tunnels and bring out large quantities of water-worn debris. The openings of the tunnels on the outer margin of the glacier, are choked with debris, the coarser part of which, as already stated, is deposited as soon as the streams have an opportunity to expand and bifurcate. With the material swept out of the tunnels there is also deposited many large bowlders as well as much small angular debris, contributed by the moraines resting on the margin of the ice. The deposits formed by the streams below the mouth of the tunnels from which they emerge, have the form of low cones, which are being built up rapidly at the apex, and consequently expand at the same time in all directions. In expanding they frequently invade and bury large areas of forested country, as already noticed in the case of the Yahtse. It is evident that so long as the margin of the Malaspina glacier remains stationary or retreats, the alluvial cones about its outer margin will continue to grow. This much of the genesis of these accumulations is a matter of observation, and affords data for judging of the character of the deposits that are being formed in the tunnels through which the glacier is drained.

The growth of the alluvial cones described above, tends to obstruct the flow of water through the tunnels connecting with them, and must cause the streams to deposit a portion of their load on the bottoms of the channels which they occupy. The water is thus brought in contact with the ice forming the roofs of the tunnels, which is melted away and gives room for a farther increase in the thickness of the subglacial stream-deposits. In the case of a stagnant ice-sheet the accumulation of gravel in the tunnels by which it is drained, would continue to increase until the water finds new channels. In this way deep narrow deposits of cross stratified gravel might be formed within a glacier, which when the ice melted would assume an anticlinal structure, owing to the displacement of the material along its sides.

In this brief digression, I have not attempted to give a complete analysis of the subglacial drainage of the Malaspina glacier; but simply endeavored to show that the tunnels through which it is drained, must be occupied in part by

gravel deposits, similar in many ways to the long, winding ridges to which the name *osar* has been applied.

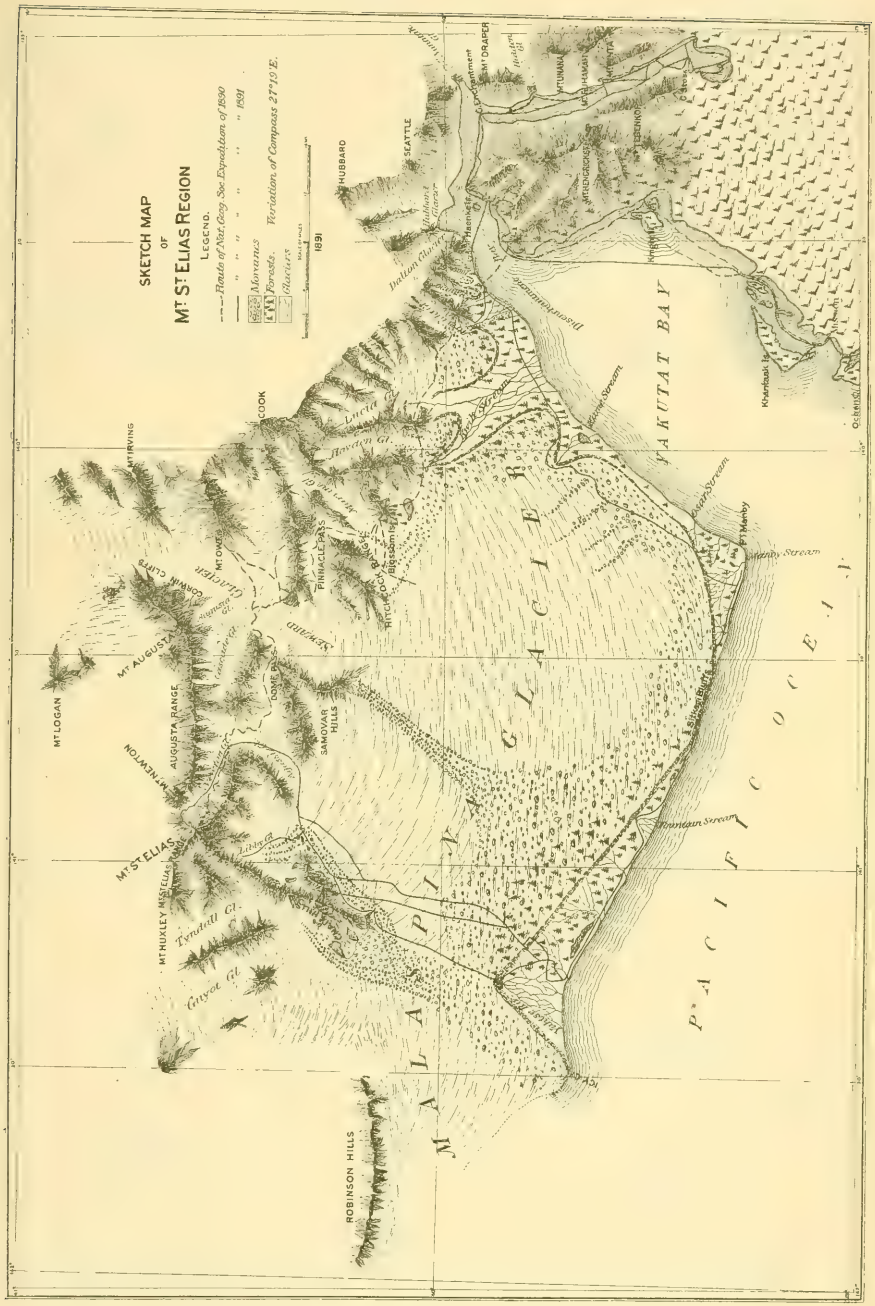
Marginal lakes.—Along the northern margin of the Malaspina glacier wherever a mountain spur projects into the ice, the rocks become warmed, and radiating heat, causes the adjacent border of the glacier to melt away. This forms a valley which becomes a line of drainage. When the streams, following the sides of a mountain spur projecting into the glacier, come together, a lake is formed which discharges through a tunnel in the ice. When the glacier passes the mouth of a lateral valley the drainage is checked and a lake formed. There are several lakes of this character about the Chaix hills. There are other methods by which the great glacier acts as a dam and cause lakes to form, but we have not time to trace out all of their histories.

These marginal lakes on the north side of the Malaspina glacier are situated at an elevation of from a thousand to fifteen hundred feet on the sides of the mountains, and receive the debris brought down by tributary streams, which is built into deltas and terraces. When the glacier melts away these deposits will be left as irregular terraces on the mountain side. Lakes will be formed about the same mountain spurs, again and again, as the surface of the ice is lowered, thus making an irregular record with considerable vertical range. It seems to me that similar records should be found on the southern slopes of the mountains of New England, and other regions, which were formerly covered by ice-sheets, analogous to the Malaspina glacier.

Photographs of the magnificent scenery of the St. Elias region were exhibited at the close of the lecture.

Art. XXI.—*Hudson River "Fiord"*; by Arthur M. Edwards, M.D.

I have been for sometime investigating the deposit thrown down during the Champlain period in the Hudson River, New York, more especially to find out if it is the same as that of the bay of Newark, N. J., and I have decided that they are different; that of Newark being newer than that of the Hudson River. But I have been called upon to examine the soundings from the Hudson River "Fiord" made by Mr. A. Lindenkohl of the U. S. Coast Survey which he has kindly furnished to me and they are with the following results. In



Map of the Mt. St. Elias Region. Scale 16 miles to the inch.